Oxford Cambridge and RSA

GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2016

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error ONLY APPLIED ONCE IN THE PAPER; also use as Repeated error
SF	Error in number of significant figures ONLY APPLIED ONCE IN THE PAPER
✓	Correct response
AE	Arithmetic error
?	Wrong physics or equation
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit

Annotation	Meaning
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:
If the data given in a question is to 2 SF, then allow answers to 2 or more SF.
If the answer is given to fewer than 2 SF, then penalise once only in the entire paper. **N.B**. Also penalise RE only once per paper.
Any exception to this rule will be mentioned in the Guidance.
A tick should be placed in the body of the script at the point where each mark is awarded.

Question			Answer	M	Guidance
1	a		resistivity = resistance x (cross-sectional) area / length	B1	**accept** equation with *resistance* as subject **allow** *over* for divide by; do **NOT** allow algebraic formula followed by a word definition of each symbol
	b	i	$A = \pi d^2/4 = 3.14 \times 10^{-6}$ m^2 $\rho = RA/l = 8.0 \times 3.14 \times 10^{-6}/ 0.15$ $\rho = 1.7 \times 10^{-4}$ unit Ω m	C1 C1 A1 B1	**apply** POT error as many times as occurs correct substitution with **ecf** for A **accept** 1.68×10^{-4} **accept** Ω mm or mΩ m, etc.
		ii 1	current below X in 'lead' equals current in 4 Ω same V across 'lead' below X and 4 Ω **or** they are in parallel (so) X is the mid point of the 'lead'/ 4 Ω is half of 8 Ω	B1 B1 B1	**allow** reverse argument starting from 4 Ω as resistance of half of 'lead' **allow** references to A_1 & A_2 possibly to indicate branches of circuit rather than meters
		ii 2	sum of R's in parallel = 2 Ω total R = 6 Ω so I = 0.50 A	C1 A1	incorrect working with correct answer cannot score second mark **allow** 0.5 A;
	c		select I = nAev = 0.40 A $v = 0.40/3.6 \times 10^{26} \times 3.14 \times 10^{-6} \times 1.6 \times 10^{-19}$ $= 2.2 \times 10^{-3}$ (m s^{-1})	C1 C1 A1	 correct substitutions into formula with **ecf** for A answer to be given to 2 or more SF
	d	i	reference to differences in <u>number density</u> of (free) electrons/charge carriers conductors have n a (few) powers of 10 <u>greater</u> than semiconductors/AW	B1 B1	allow n, number per m^3 or unit volume **allow** <u>much</u> greater than
		ii	*conductor*: R or ρ rises because of (increase in) electron ion collisions/ v falls *semiconductor*: R or ρ falls because of (large) increase in n/free electrons	B1 B1	**allow** R or resistivity rises for conductors and falls for semiconductors for 1 mark **allow** current decreases for same p.d. /AW **allow** current increases for same p.d. /AW
			Total question 1	**17**	

Question			Answer	M	Guidance
2	**a**	**i**	straight line through origin passing through (2, 30)	B1 B1	 **allow** 2.0 ± 0.05, i.e. half a square
		ii	V is <u>proportional</u> to I for the resistor R but the LED the characteristic/line is a curve/not a straight line	B1 B1	**accept** statement of Ohm's law **allow** V α I **NOT** gradient changes **nor** gradient not constant
	b	**i**	From Fig. 2.1, V <u>across R</u> at 30 mA = 2.0 V **or** 0.03 x 67 = 2.0 V V <u>across LED</u> = 5.0 – 2.0 = 3.0 V I in LED at 3.0 V is 30 mA	 B1 B1 B1	**allow** 1 SF answers in **b(i)** and **(ii)** at 30 mA R of LED = 100 Ω total R = 167 Ω I in LED = 5.0/167 = 30 mA **or** in reverse
		ii 1	0.030 (C)	A1	**allow** 30 mC or 3.0 x 10^{-2} C
		ii 2	QV or VI = 3.0 x 0.03 **or** $I^2R = 0.03^2$ x 100 energy = 0.090 (J)	C1 A1	**possible ecf from (ii)1** **allow** 90 mJ or 9.0 x 10^{-2} J **allow** 1 mark for 0.15 (J), i.e. taking V = 5 V
		ii 3	$P = I^2R = 0.03^2$ x 67 = 0.060 (J)	C1 A1	**possible ecf from b(i) for R value** **allow** P = VI = 2.0 x 0.03 = 0.060 J **or** $P = V^2/R = 2.0^2/67$ = 0.0597 J
		iii	current required is 0.63 A so nearest larger value is best 1.0 A	M1 A1	
	c		suitable example, e.g. torch bulb, traffic light, car rear lamp,etc. (replaced by cluster of LEDs) advantage, e.g. draws a lower current/ more efficient (at converting electrical energy into light)/if one LED fails others are still lit/greater lifetime/more robust	B1 B1	**accept** TV screens etc. **allow** size e.g. back lighting in mobile **NOT** cost
			Total question 2	**16**	

Question			Answer	M	Guidance
3	a		energy	A1	
	b	i	energy (**available) to be** transferred from electrical to other forms **per unit charge** **or** energy transferred **across the terminals** from the supply **per unit charge**	B1 B1	**award** 1 mark for only one of the two bold phrases; 2 marks for both present **allow** 1 mark for answer which uses V = E - Ir with explanation **or** the p.d. across (the terminals of) the supply when it is delivering a current (to an external circuit)
		ii	The supply behaves as if it has an (internal) resistance causing (some) energy to be *transferred into thermal energy/lost as heat* **or** there is a *voltage drop across/decrease in voltage* from the supply when a current is drawn from it/AW	B1	**NOT** the energy lost as heat inside the supply **allow** (causes) 'lost volts' per unit current (in the supply)
	c	i	Take readings of V and I for several (five or more) positions/values of the variable resistor plot a graph of V against I the internal resistance is constant if the graph of V against I is a straight line measure the gradient of the V against I graph which equals the internal resistance **or** find y-intercept = E; find one pair of values of V,I substitute into equation E = V + Ir to find r	B1 B1 B1 B1 B1	**Do not allow** any analysis with E assumed to be 6 V **allow** 2 pairs of values of V and I to be substituted into equation to find r (non-graph method max 2/5) **allow** find or similar word ignore problem of minus sign, i.e. assume value only
		ii	as a safety/limiting resistor **or** so the supply is not short-circuited (when variable resistor is reduced to zero)/AW	B1	**allow** e.g. to stop the current becoming too large/AW
	d	i	arrow pointing clockwise	A1	arrow need not be on circuit wire
		ii	e.m.f = 4.5 – 2.4 (= 2.1 V) I = 2.1/(0.6 + 0.4 + 2.0) = 2.1/3.0 = 0.70 A	C1 A1	 **allow** 0.7 A
		iii 1	1.4 (V)	A1	**ecf(d)(ii)** i.e. answer = 2 x ans(d)(ii) **NOT** ecf when I = 1.05 A/3.45 A giving 2.1 V/6.9 V
		iii 2	V_x = 4.5 – 0.70 x 0.6 4.1 (V)	C1 A1	**ecf(d)(ii)**
			Total question 3	**16**	

Question			Answer	M	Guidance
4	a		All of the r*ays/wavefronts/waves* are added together (at each point on the screen) when the path difference is an exact number of wavelengths the *rays/waves* interfere constructively giving maximum amplitude/intensity (at all other angles) when the path difference between rays is not an exact number of wavelengths the *rays/waves interfere destructively/cancel out* giving *a dark background/little to no intensity*	B1 B1 B1 B1 B1 B1	**max** 4 marks to include the second marking point **NOT** *superpose* or *interfere* for *added* as in stem of Q **allow** nλ **QWC mark** **allow** bright *line/light* **NOT** bright fringes **nor** maxima **NOT** when the path difference is (2n +1)λ/2 there is destructive interference/AW **allow** suitable annotation of diagram to score marks
	b	i 1	two lines between 5 and 15 degrees (judge by eye)	B1	**allow** with label C missing; actual value is 12.5^o
		i 2	select nλ = d sin θ 579×10^{-9} = d sin 20 = 0.342 d d = 1.7×10^{-6} (m)	C1 C1 A1	**allow** n = 1 in initial equation allow 1.69×10^{-6}
		ii	**E**	B1	
		iii	**D,E**	B1	
		iv	E = 3.64×10^{-19} J select E = hc/ λ , λ = $6.63 \times 10^{-34} \times 3.0 \times 10^{8}/3.64 \times 10^{-19}$ λ = 5.46×10^{-7} m **D**	C1 B1 A1 A0	**accept** 546 nm; **N.B.** a correct unit must be present
		v	lines appear at the same *positions/frequencies* in the spectrum **emission**: *bright/coloured* lines (on dark background) **absorption**: *dark/black* lines (on *bright background/continuous spectrum*)	B1 B1	**allow** comparison of backgrounds only **or** just a full description of absorption spectrum
		vi	E = (3.1 + 4.7) x 10^{-19} J = 7.8×10^{-19} J select E = hc/ λ , λ = $6.63 \times 10^{-34} \times 3.0 \times 10^{8}/7.8 \times 10^{-19}$ λ = 2.55×10^{-7} m	B1 B1 A1	E = $6.63 \times 10^{-34} \times 3.0 \times 10^{8}/2.54 \times 10^{-7}$ giving E = 7.8(3) x 10^{-19} J (f = 1.18×10^{15} Hz) which equals (3.1 + 4.7) x 10^{-19} J
			Total question 4	**18**	

Question			Answer	M	Guidance
5	a	i	λ **minimum** distance between ***neighbouring/adjacent*** identical points on the wave f number of (complete) *oscillations/cycles/vibrations* (at a point) per unit time **or** produced by the wave source per unit time T time for one complete oscillation **or** time for one complete oscillation at a point on the wave	B1 B1 B1	**N.B.** one of the two emboldened words must be present ;**allow** e.g distance from one peak to the next peak of the wave **allow** number of wavelengths passing a point per unit time; **allow** per second **NOT** amount **NOT** in a second **nor** f = 1/T **allow** time for one wavelength to pass a (given) point **NOT** time for one oscillation to pass **nor** T = 1/f **N.B.** if f=1/T or T = 1/f is included in an otherwise correct definition ignore, do not CON
		ii	speed = (distance of) one wavelength travelled per period where period equals 1/frequency so v = λ/(1/f) =f λ **or** in 1 second f wavelengths λ are produced distance travelled by first wavelength in one second is f λ = v	M1 M1 A1	**allow** v = λ/T but T = l/f so v = λ/(1/f) =f λ **NOT** derivation in terms of units
	b	i 1	¾ λ with node at closed end and antinode at open end	B1	**allow** poorly proportioned sketches which reach both ends
		i 2	all nodes and antinodes drawn in **bi1** correctly labelled N and A only two N and two A present	B1 B1	positions of labels must be accurate to the eye **allow** max of one mark for only 3 out of the 4 labelled
		ii	λ/2 = 33 cm v = fλ = 512 x 0.66 v = 338 or 340 (m s^{-1})	C1 C1 A1	**or** λ/4 = 16.5 cm **N.B.** an incorrect value of λ/4 or λ/2 scores 0/3
	c	i	the pipe is one wavelength long with both ends antinodes so sketch must have 3 antinodes and 2 nodes with reasonably correct proportions	B1	
		ii1	256 (Hz)	B1	
		ii2	λ/2 with antinodes at both ends	B1	
		iii	v is the same in the pipe at all f/length is fixed = $\lambda_0/2 = \lambda_1$ so as $f_1 \lambda_1 = f_0 \lambda_0$ then $f_1 = 2f_0$ **or** harmonics must have antinodes at both ends of the pipe so next possible pattern is *one wavelength/has 3A and 2N*	B1 B1	**allow** 1 mark for: as $f_1 = 2f_0$ then f_1 is the second harmonic **or** halving the wavelength doubles the frequency
			Total question 5	**17**	

Question			Answer	M	Guidance
6	a	i	λ is the (de Broglie) wavelength associated with a particle h is (a constant known as) the Planck constant mv is the momentum/mass x speed of the particle	B1 B1 B1	**allow** object/electron for particle **accept** velocity for speed **accept** m and v separately but the particle must appear with one of the quantities to score the mark
		ii	electrons passing through a (thin) sheet of graphite are diffracted producing *rings/pattern* (on a fluorescent screen)	B1 A1	any suitable situation **NOT** Au or Al, etc. what is observed + interpretation 1 mark. **Do not** award the A mark alone unless a plausible situation has been suggested. *Young slits* type experiments etc score 0/2
		iii 1	$eV = ½ mv^2$ $2eV/m = v^2$ so $v = \sqrt{(2 \times 1.6 \times 10^{-19} \times 5.0 \times 10^4/9.1 \times 10^{-31})}$ so $v = 1.3 \times 10^8$ (m s^{-1})	C1 C1 B1 A0	**allow** $eV = 8.0 \times 10^{-15}$ J for 1 mark **allow** $\sqrt{(2 \times 8.0 \times 10^{-15} /9.1 \times 10^{-31})}$ **or** evidence of correct calculation, e.g. $v = 1.325 \times 10^8$
		iii 2	$\lambda = h/mv = 6.63 \times 10^{-34}/ 1.3 \times 10^8 \times 9.1 \times 10^{-31}$ $\lambda = 5.6 \times 10^{-12}$ (m)	C1 A1	 **allow** 5.5×10^{-12} if 1.325×10^8 is used
		iii 3	λ of visible light 5.6×10^{-7} m so power of 10 = 5 or -5	B1 B1	**ecf aiii2**; **accept** 4 to 7 x 10^{-7} m **NOT** 10^{-7} **NOT** 10^5 on the answer line
	b		The photoelectric effect Individual photons are absorbed by individual electrons in the metal surface, i.e. one to one interaction. Only photons with energies above the work function energy will cause photoelectron emission/idea of threshold frequency Hence u-v photons or blue photons will cause photoemission but red photons will not. Number of electrons emitted depends on light intensity A wave model does not explain instantaneous emission of electrons. A wave model does not explain a threshold frequency/wavelength for emission to occur	B1 B1 B1 B1 B1 B1 B1	QWC mark **allow** exp't description: uv light shone on a zinc plate connected to a gle **max** 3 from 6 marking points **allow** wave model does not explain no emission however bright the light if energy of photon below work function
			Total question 6	**16**	

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